SPECIFICATION

METHOD OF JUDGING TRUTH OF PAPER TYPE

<Technical Field>

The present invention relates to a method of judging the truth of a paper type such as a bill or a security.

<Background Art>

Known as a method of judging the truth of a bill is a method of judging the truth of a bill to be examined by comparing detection data obtained by a single sensor such as a magnetic sensor from the bill to be examined with reference data previously produced (JP-B-60-215293).

In this method, however, only the data detected by the single sensor is used for judging the truth. If it is judged how sensor is used as the sensor, it is easy to fabricate such a false bill that data which is judged to be a true bill by the sensor is obtained. That is, it is easy to counterfeit a bill.

Therefore, a method of judging the truth of a bill using two types of sensors (see JP-A-51-90890 and JP-A-51-90891). That is, a first sensor for detecting the transmission rate of visible light in

a portion to be examined of a bill to be examined and a second sensor for detecting the transmission rate of infrared light in the portion to be examined of the bill to be examined are prepared, and it is judged whether or not the ratio of the detection level of the transmission rate of the visible light detected by the first sensor to the detection level of the transmission rate of the infrared light detected by the second sensor or the difference therebetween is within a predetermined range, to judge the truth of the bill to be examined.

Although this method also uses the two sensors, however, the truth is judged by simple judgment whether or not the difference or the ratio between the detection levels of the sensors is within a predetermined range. If it is judged how sensors are used as the sensors, it is easy to fabricate such a false bill that data which is judged to be a true bill by the sensors is obtained. That is, it is easy to counterfeit a bill.

An object of the present invention is to provide a method of judging the truth of a paper type which is more difficult to counterfeit.

<Disclosure of Invention>

A method of judging the truth of a paper type

according to the present invention is characterized by measuring, with respect to each of true paper types previously prepared, a plurality of types of characteristic amounts by a plurality of types of sensors for each of a plurality of portions for examination previously determined, analyzing principal components on the basis of obtained results of the measurement, to find an equation of straight line corresponding to the predetermined principal component, and producing reference data composed of a value relating to the predetermined principal component for the portion for examination on the basis of the found equation of straight line; measuring, with respect to the paper type to be examined, the plurality of types of characteristic amounts by the plurality of types of sensors for each of the plurality of portions for examination previously determined, and producing data for examination composed of a value relating to the predetermined principal component for the portion for examination on the basis of obtained results of the measurement and the equation of straight line; and comparing the reference data and the data for examination, to judge the truth of the paper type to be examined.

Used as the plurality of types of sensors are two types of sensors, i.e., a magnetic sensor and a light transmission sensor. Used as the plurality of types of sensors are two types of sensors, i.e., a red light transmission sensor and an infrared light transmission sensor. Used as the plurality of types of sensors are three types of sensors, for example, a magnetic sensor, a red light transmission sensor, and an infrared light transmission sensor.

<Brief Description of the Drawings>

Fig. 1 is a plan view showing a sensor for reading characteristic amounts of a bill;

Fig. 2 is a flow chart showing the procedure for preliminary processing for producing reference data;

Figs. 3(a) and 3(b) are graphs schematically showing data representing a detected value x_1 by a light transmission sensor 11 for each of positions on a line L and data representing a detected value x_2 by a magnetic sensor 12 for each of the positions on the line L;

Fig. 4 is a graph for explaining a method of analyzing principal components;

Fig. 5 is a graph schematically showing reference data relating to a first principal

component;

Fig. 6 is a flow chart showing the procedure for truth judgment processing of a bill to be examined;

Fig. 7 is a plan view showing a sensor for reading characteristic amounts of a bill;

Fig. 8 is a front view showing a sensor for reading characteristic amounts of a bill;

Fig. 9 is a flow chart showing the procedure for preliminary processing for producing reference data;

Figs. 10(a) and 10(b) are graphs schematically showing data representing a detected value y_1 by a first light transmission sensor 21 for each of positions on a line L and data representing a detected value y_2 by a second light transmission sensor 22 for each of the position on the line L;

Fig. 11 is a graph for explaining a method of analyzing principal components;

Fig. 12 is a flow chart showing the procedure for truth judgment processing of a bill to be examined; and

Fig. 13 is a graph for explaining a method of analyzing principal components.

<Best Mode for Carrying out the Invention>

Referring now to the drawings, embodiments of the present invention will be described.

[1] Description of First Embodiment

[1-1] Description of Sensor for Reading Characteristic Amounts of Bill

Fig. 1 illustrates a sensor for reading characteristic amounts of a bill.

A bill 1 is fed into an examining device (not shown) and is conveyed in a direction indicated by an arrow. As a sensor for reading characteristic amounts of the bill 1, a light transmission sensor 11 and a magnetic sensor 12 are provided.

The light transmission sensor 11 detects the light transmission rate at a plurality of positions where characteristic amounts are read on a line L in the bill 1. The magnetic sensor 12 detects magnetic field strength at each of the positions where characteristic amounts are read on the line L in the bill 1.

[1-2] Description of Preliminary Processing

In order to judge the truth of a bill, reference data must be produced on the basis of a plurality of true bills previously prepared.

Fig. 2 shows the procedure for preliminary processing for producing reference data.

(1) A plurality of true bills are previously prepared. With respect to each of the true bills, a detected value x_1 by the light transmission sensor 11 and a detected value x_2 by the magnetic sensor 12 are accepted for each of a plurality of positions where characteristic amounts are read on a line L (step 1).

Consequently, data (Fig. 3 (a)) representing the detected value x_1 by the light transmission sensor 11 for each of the positions on the line L and data (Fig. 3 (b)) representing the detected value x_2 by the magnetic sensor 12 for each of the positions on the line L are obtained, as shown in Figs. 3 (a) and 3 (b), with respect to one of the true bills.

(2) An equation of straight line Z_1 corresponding to a first principal component and an equation of straight line Z_2 corresponding to a second principal component are found from the data obtained with respect to all the true bills by a principal component analyzing method (step 2).

Specifically, a point graph is prepared using the detected value x_1 by the light transmission sensor 11 to enter the vertical axis and using the detected value x_2 by the magnetic sensor 12 to enter the horizontal axis as to the data (x_1, x_2) obtained

for each of the positions on the line L with respect to all the true bills.

Such a first straight line (a Z_1 axis) that the sum of the squares of the lengths of perpendicular lines drawn from respective points out of straight lines passing through the center of gravity (an average) Q of the detected value x_1 by the light transmission sensor 11 and the detected value x_2 by the magnetic sensor 12 is the smallest is drawn. Further, a second straight line (a Z_2 axis) passing through the center of gravity Q and perpendicular to the Z_1 axis is drawn.

Z_1 denotes a first principal component, and Z_2 denotes a second principal component. The first principal component represents the degree of magnetic ink, and the second principal component represents the quality of ink. The distance of each of the points from the center of gravity Q on the straight line Z_1 in Fig. 4 refers to a first principal component score. The distance of each of the points from the center of gravity Q on the straight line Z_2 in Fig. 4 refers to a second principal component score.

The first equation of straight line Z_1 and the second equation of straight line Z_2 which are

expressed by the following equation (1) are found:

$$Z_1 = a_1 \cdot x_1 + b_1 \cdot x_2$$

$$Z_2 = a_2 \cdot x_1 + b_2 \cdot x_2 \quad \cdots (1)$$

A method of finding coefficients a_1, a_2, b_1, and b_2 are well-known and hence, is omitted.

(3) Data representing the first principal component score for each of the positions on the line L and data representing the second principal component score for each of the positions on the line L are then produced for each of the true bills (step 3).

A method of producing the data representing the first principal component score for each of the positions on the line L and the data representing the second principal component score for each of the positions on the line L with respect to one of the true bills will be described.

Data (x_1, x_2) for each of the positions on the line L with respect to one arbitrary true bill in Fig. 4 is converted into a value in a system of coordinates formed by the Z_1 axis and the Z_2 axis with the center of gravity Q at the origin. In other words, a first principal component score and a second principal component score represented by the data (x_1, x_2) for each of the positions on the line L with

respect to one arbitrary true bill in Fig. 4 are found.

Specifically, the data (x_1, x_2) for each of the positions on the line L with respect to the one true bill is first substituted in the equation 1, to find values of Z_1 and Z_2 for the position on the line L. An average $*Z_1$ of Z_1 obtained for the positions on the line L and an average $*Z_2$ of Z_2 obtained for the positions on the line L are found. The average $*Z_1$ is subtracted from Z_1 obtained for each of the positions on the line L, to find a first principal component score for the position on the line L. Further, the average $*Z_2$ is subtracted from Z_2 obtained for each of the positions on the line L, to find a second principal component score for the position on the line L.

Consequently, data representing the first principal component score for each of the positions on the line L and data representing the second principal component score for each of the positions on the line L are produced with respect to the true bill.

(4) An average of the first principal component scores with respect to all the true bills is found for each of the positions on the line L, thereby

producing data representing the average of the first principal component scores for the position on the line L (step 4). Consequently, reference data relating to the first principal component is produced, as shown in Fig. 5, for example.

(5) Furthermore, an average of the second principal component scores with respect to all the true bills is found for each of the positions on the line L, thereby producing data representing the average of the second principal component scores for the position on the line L (step 5). Consequently, reference data relating to the second principal component is produced.

[1-3] Description of Method of Judging Truth of Bill to be Examined

Fig. 6 shows the procedure for truth judgment processing of a bill to be examined.

(1) With respect to a bill to be examined, a detected value x_1 by the light transmission sensor 11 and a detected value x_2 by the magnetic sensor 12 are accepted for each of a plurality of positions where characteristic amounts are read on a line L (step 11).

Consequently, data representing the detected value x_1 by the light transmission sensor 11 for each

of the positions on the line L and data representing the detected value x_2 by the magnetic sensor 12 for each of the positions on the line L are obtained with respect to the bill to be examined.

(2) With respect to the bill to be examined, data representing a first principal component score for each of the positions on the line L (data for examination relating to a first principal component) and data representing a second principal component score for each of the positions on the line L (data for examination relating to a second principal component) are produced (step 12).

Data (x_1, x_2) for each of the positions on the line L with respect to the bill to be examined is first substituted in the equations of straight line Z_1 and Z_2 (the above-mentioned equation 1) found in the preliminary processing, to find values of Z_1 and Z_2 for the position on the line L. An average $*Z_1$ of Z_1 obtained for the positions on the line L and an average $*Z_2$ of Z_2 obtained for the positions on the line L are found. The average $*Z_1$ is subtracted from Z_1 obtained for each of the positions on the line L, to find a first principal component score for the position on the line L. Further, the average $*Z_2$ is subtracted from Z_2 obtained for each of the

positions on the line L, to find a second principal component score for the position on the line L.

Consequently, data for examination relating to the first principal component (data representing the first principal component score for each of the positions on the line L) and data for examination relating to the second principal component (data representing the second principal component score for each of the positions on the line L) are produced with respect to the bill to be examined.

(3) A correlation value (a correlation value relating to the first principal component) between the data for examination relating to the first principal component found from the bill to be examined and reference data relating to the first principal component found by the preliminary processing is calculated (step 13). That is, the square of the difference between data values at the same position for examination of the data for examination relating to the first principal component found from the bill to be examined and the reference data relating to the first principal component is calculated, and the sum of the squares of the differences at the obtained positions for examination is then calculated. The result of the

calculation is a correlation value relating to the first principal component.

(4) The correlation value relating to the first principal component and a predetermined threshold are compared with each other (step 14).

(5) When the correlation value relating to the first principal component is more than the predetermined threshold, the bill to be examined is judged to be a false bill (step 15).

(6) When the correlation value relating to the first principal component is not more than the predetermined threshold, a correlation value (a correlation value relating to the second principal component) between the data for examination relating to the second principal component found from the bill to be examined and reference data relating to the second principal component found by the preliminary processing is calculated (step 16). That is, the square of the difference between data values at the same position for examination of the data for examination relating to the second principal component found from the bill to be examined and the reference data relating to the second principal component is calculated, and the sum of the squares of the differences at the obtained positions for

examination is then calculated. The result of the calculation is a correlation value relating to the second principal component.

(7) The correlation value relating to the second principal component and a predetermined threshold are compared with each other (step 17).

(8) When the correlation value relating to the second principal component is more than the predetermined threshold, the bill to be examined is judged to be a false bill (step 18).

(9) When the correlation value relating to the second principal component is not more than the predetermined threshold, the bill to be examined is judged to be a true bill (step 18).

Although in the above-mentioned first embodiment, the reference data relating to each of the principal components is found by finding an average of the principal component scores with respect to all the true bills for each of the positions on the line L, an average of values of principal components (values of Z) for each of the positions on the line L with respect to all the true bills may be found to produce reference data relating to the principal components.

The reference data relating to the first

principal component will be described. At the step 3 shown in Fig. 2, the data (x_1, x_2) for each of the positions on the line L is substituted in the equation 1 with respect to each of the true bills, to find the value of Z_1 for the position on the line L. At the step 4 shown in Fig. 2, an average of the values of Z_1 with respect to all the true bills is found for each of the positions on the line L, thereby producing reference data relating to the first principal component.

When the reference data is used, used as data for examination relating to each of the principal components is data composed of the value of the principal component for each of the positions on the line L with respect to the bill to be examined.

Description is made of the data for examination relating to the first principal component. At the step 12 shown in Fig. 6, the data (x_1, x_2) for each of the positions on the line L with respect to the bill to be examined is substituted in the equation of straight line Z_1 (the above-mentioned equation 1) found in the preliminary processing, to find the value of Z_1 for the position on the line L, thereby producing the data for examination relating to the first principal component.

[2] Description of Second Embodiment

[2-1] Description of Sensor for Reading Characteristic Amounts of Bill

Figs. 7 and 8 illustrate a sensor for reading characteristic amounts of a bill.

A bill 1 is fed into an examining device (not shown) and is conveyed in a direction indicated by an arrow. As a sensor for reading characteristic amounts of the bill 1, a first light transmission sensor 21 and a second light transmission sensor 22 are provided.

The light transmission sensor 21 is constituted by a light emitting diode 21a for irradiating red light having a wavelength λ of 655 nm onto a plurality of positions where characteristic amounts are read on a surface of a bill 1 and on a line L and a photosensor 21b for receiving infrared light emitted from the light emitting diode 21a and passing through the bill 1.

The second light transmission sensor 22 is constituted by a light emitting diode 22a for irradiating infrared light having a wavelength λ of 840 nm onto the plurality of positions where characteristic amounts are read on the surface of the bill 1 and on the line L and a photosensor 22b

for receiving red light emitted from the light emitting diode 22a and passing through the bill 1.

The light emitting diode 21a and the light emitting diode 22a are alternately driven, thereby obtaining outputs of both the photosensors 21b and 22b at each of the positions where characteristic amounts are read on the line L in the bill 1.

[2-2] Description of Preliminary Processing

In order to judge the truth of a bill, reference data must be produced on the basis of a plurality of true bills previously prepared.

Fig. 9 shows the procedure for preliminary processing for producing reference data.

(1) A plurality of true bills are previously prepared. With respect to each of the true bills, a detected value y_1 by the first light transmission sensor 21 and a detected value y_2 by the second light transmission sensor 22 are accepted for each of a plurality of positions where characteristic amounts are read on a line L (step 21).

Consequently, data (Fig. 10 (a)) representing the detected value y_1 by the first light transmission sensor 21 for each of the positions on the line L and data (Fig. 10 (b)) representing the detected value y_2 by the second light transmission sensor 22

for each of the positions on the line L are obtained, as shown in Figs. 10 (a) and 10 (b), with respect to one of the true bills.

(2) An equation of straight line Z_1 corresponding to a first principal component and an equation of straight line Z_2 corresponding to a second principal component are found from the data obtained with respect to all the true bills by a principal component analyzing method (step 2).

Specifically, a point graph is prepared using the detected value y_1 by the first light transmission sensor 21 to enter the vertical axis and using the detected value y_2 by the second light transmission sensor 22 to enter the horizontal axis as to the data (y_1, y_2) obtained for each of the positions on the line L with respect to all the true bills.

Such a first straight line (a Z_1 axis) that the sum of the squares of the lengths of perpendicular lines drawn from respective points out of straight lines passing through the center of gravity (an average) Q of the detected value y_1 by the first light transmission sensor 21 and the detected value y_2 by the second light transmission sensor 22 is the smallest is drawn. Further, a second straight line (a Z_2 axis) passing through the center of gravity

Q and perpendicular to the Z_1 axis is drawn.

Z_1 denotes a first principal component, and Z_2 denotes a second principal component. The first principal component represents the gradation of ink, and the second principal component represents the quality of ink. The distance of each of the points from the center of gravity Q on the straight line Z_1 in Fig. 11 refers to a first principal component score. The distance of each of the points from the center of gravity Q on the straight line Z_2 in Fig. 11 refers to a second principal component score.

The first equation of straight line Z_1 and the second equation of straight line Z_2 which are expressed by the following equation (2) are found:

$$Z_1 = a_1 \cdot y_1 + b_1 \cdot y_2$$

$$Z_2 = a_2 \cdot y_1 + b_2 \cdot y_2 \quad \cdots (2)$$

A method of finding coefficients a_1, a_2, b_1, and b_2 are well-known and hence, is omitted.

(3) Data representing the first principal component score for each of the positions on the line L and data representing the second principal component score for each of the positions on the line L are then produced for each of the true bills (step 23). A method of producing the data is the same method as that at the step 3 shown in Fig. 2 in the

first embodiment and hence, the description thereof is not repeated.

(4) An average of the first principal component scores with respect to all the true bills is found for each of the positions on the line L, thereby producing data representing the average of the first principal component scores for the position on the line L (step 24). Consequently, reference data relating to the first principal component is produced.

(5) Furthermore, an average of the second principal component scores with respect to all the true bills is found for each of the positions on the line L, thereby producing data representing the average of the second principal component scores for the position on the line L (step 25). Consequently, reference data relating to the second principal component is produced.

[2-3] Description of Method of Judging Truth of Bill to be Examined

Fig. 12 shows the procedure for truth judgment processing of a bill to be examined.

(1) With respect to a bill to be examined, a detected value y_1 by the first light transmission sensor 21 and a detected value y_2 by the second light

transmission sensor 22 are accepted for each of a plurality of positions where characteristic amounts are read on a line L (step 31).

Consequently, data representing the detected value y_1 by the first light transmission sensor 21 for each of the positions on the line L and data representing the detected value y_2 by the second light transmission sensor 22 for each of the positions on the line L are obtained with respect to the bill to be examined.

(2) With respect to the bill to be examined, data representing a first principal component score for each of the positions on the line L (data for examination relating to a first principal component) and data representing a second principal component score for each of the positions on the line L (data for examination relating to a second principal component) are produced (step 32). A method of producing the data is the same as that at the step 12 shown in Fig. 2 in the first embodiment and hence, the description thereof is not repeated.

(3) A correlation value (a correlation value relating to the first principal component) between the data for examination relating to the first principal component found from the bill to be

examined and reference data relating to the first principal component found by the preliminary processing is calculated (step 33). That is, the square of the difference between data values at the same position for examination of the data for examination relating to the first principal component found from the bill to be examined and the reference data relating to the first principal component is calculated, and the sum of the squares of the differences at the obtained positions for examination is then calculated. The result of the calculation is a correlation value relating to the first principal component.

(4) The correlation value relating to the first principal component and a predetermined threshold are compared with each other (step 34).

(5) When the correlation value relating to the first principal component is more than the predetermined threshold, the bill to be examined is judged to be a false bill (step 35).

(6) When the correlation value relating to the first principal component is not more than the predetermined threshold, a correlation value (a correlation value relating to the second principal component) between the data for examination relating

to the second principal component found from the bill to be examined and reference data relating to the second principal component found by the preliminary processing is calculated (step 36). That is, the square of the difference between data values at the same position for examination of the data for examination relating to the second principal component found from the bill to be examined and the reference data relating to the second principal component is calculated, and the sum of the squares of the differences at the obtained position for examination is then calculated. The result of the calculation is a correlation value relating to the second principal component.

(7) The correlation value relating to the second principal component and a predetermined threshold are compared with each other (step 37).

(8) When the correlation value relating to the second principal component is more than the predetermined threshold, the bill to be examined is judged to be a false bill (step 35).

(9) When the correlation value relating to the second principal component is not more than the predetermined threshold, the bill to be examined is judged to be a true bill (step 38).

Also in the above-mentioned second embodiment, an average of values of principal components (values of Z) with respect to all the true bills for each of the positions on the line L may be found to produce reference data relating to the principal components. When the reference data is used, used as data for examination relating to each of the principal components is data composed of the value of the principal component (the value of Z) for each of the positions on the line L with respect to the bill to be examined.

[3] Description of Another Embodiment

Although in the first embodiment and the second embodiment, the truth of the bill is judged using two types of sensors, the truth of the bill can be also judged using three types of sensors.

An example using a magnetic sensor, an infrared light transmission sensor (a first light transmission sensor), a read light transmission sensor (a second light transmission sensor), for example, will be briefly described.

When the three types of sensors are used, three principal components Z_1, Z_2, and Z_3 which are perpendicular to one another are found by a principal component analyzing method, as shown in Fig. 13. The

principal component Z_1 represents the gradation of ink, the principal component Z_2 represents the quality of ink (an optical element), and the principal component Z_3 represents the quality of ink (a magnetic element).

In preliminary processing, three types of sensor values (an infrared light transmission sensor value, a read light transmission sensor value, and a magnetic sensor value) for each of positions on a line L are measured from a plurality of true bills, to produce reference data for each of the principal components Z_1, Z_2, and Z_3 (data representing an average of principal component scores or values of Z for each of the positions on the line L) from the measured values.

In truth judgment processing of the bill to be examined, three types of sensor values (an infrared light transmission sensor value, a red light transmission sensor value, and a magnetic sensor value) for each of the positions on the line L are measured from the bill to be examined, to calculate data for examination (data representing the principal component score or the value of Z for the position on the line L) for each of the principal components Z_1, Z_2, and Z_3 from the measured values.

A correlation value between the data for examination obtained from the bill to be examined and the reference data is calculated for each of the principal components, and the obtained correlation value and a predetermined threshold are compared with each other, to judge the truth of the bill to be examined.

According to the present invention, a method of judging the truth of a paper type which is difficult to counterfeit is obtained.